Short communication

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Efficient coding in dolphin surface behavioural patterns

Ramon Ferrer i Cancho[1,*]

[1]Departament de Fisica Fonamental, Universitat de Barcelona, Marti i Franquès 1, Barcelona, 08028, Spain.

David Lusseau[2]

[2]Dalhousie University, Department of Biology, 1355 Oxford Street, Halifax, NS B3H 4J1, Canada.

(*) Phone: +34 934024257. Fax: +34 934021149.

E-mail: ramon.ferrericancho@gmail.com.

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Words that are more frequently used tend to be shorter in human language [1, 2] (Fig. 1 (a)). The length of a word can be measured in letters or phonemes. The shortening of words with frequency can be regarded as evidence of efficient coding: by employing shorter codes for more frequent words, it is possible to increase the rate of information transmitted [3]. This tendency is the rationale behind file compression techniques such as Huffman codes [4]. Efficient coding has not been reported in other species to our knowledge. Here we will provide the first evidence of a negative correlation between frequency and code size in the surface behavioural patterns of bottlenose dolphins (*Tursiops* sp.).

Surface behavioural patterns represent a series of body movement, behavioural units, which can be clearly distinguished as a bout at the water surface. Our standard classification of behavioural patterns has been used to define the ethogram of dolphin populations in many previous studies (see [5] for a review). Patterns, described in [5], were defined to be mutually exclusive and cumulatively inclusive. As a whole they describe the entire behavioural repertoire of the bottlenose dolphin population living in Doubtful Sound, New Zealand, that can be observed at the surface. Here we defined behavioural units which were unambiguously representing distinct parts in the body movement which represented behavioural patterns. They were also defined to be mutually exclusive. We defined these units and pattern composition independently from this study and prior to it. Thus, this analysis did not influence the definition of units and patterns. These behavioural units can be used in different combinations to produce different behavioural patterns which in many cases involve more than one behavioural unit (Table 1). For instance, the pattern “lobtail” involves three behavioural units:

"stationary", "hit" and "tail". By changing "hit" with "expose" we obtain a different behavioural pattern ("tail-out").

Dolphin surface behavioural patterns share some features with human words: both form sequences with long-distance correlations [6] and both are used to communicate [5]. Studies have revealed the meaning of some patterns (see [5] for review). For instance, percussive patterns, such as lobtail, have been argued to convey information about individual's intentions (Lusseau 2006). Similarly, side-flop and upside-down lobtail are used to communicate intention to shift activity state in order to maintain the activity of the dolphin school synchronised [7].

Following the metaphor of human language, dolphin surface behavioural patterns can be thought of as words and their behavioural units as letters (or phonemes). We aim to investigate whether there is a tendency for behavioural patterns to be smaller as more frequent words are made of fewer letters. This hypothesis was supported by a Pearson's correlation test on pattern frequency versus pattern size (N=31, r=-0.484, p=0.006; Fig. 1 (b)) for the data studied in [5,6]. A correlation between pattern size and frequency could have occurred by chance because pattern size variation was small (Table 1). We therefore carried out a randomisation test to find out whether a similar correlation coefficient could have occurred if pattern size was randomly assigned to patterns. We randomly assigned a size to each pattern from the known pattern size distribution (sampling without replacement) 1000 times and calculated each time the correlation between pattern size and frequency. The correlation coefficients of the randomised data were significantly lower than the observed correlation coefficient ($\bar{r}_{rand} = 0.004$, 95% confidence interval: -0.336 to +0.373). The correlation was significant in 4.9% of 1000 randomisations and $p<0.006$ in 0.8%. Therefore it was significantly unlikely that the observed correlation had occurred by chance. Our findings indicate that dolphins use

smaller codes for more frequent patterns, suggesting that coding efficiency is not unique to human language.

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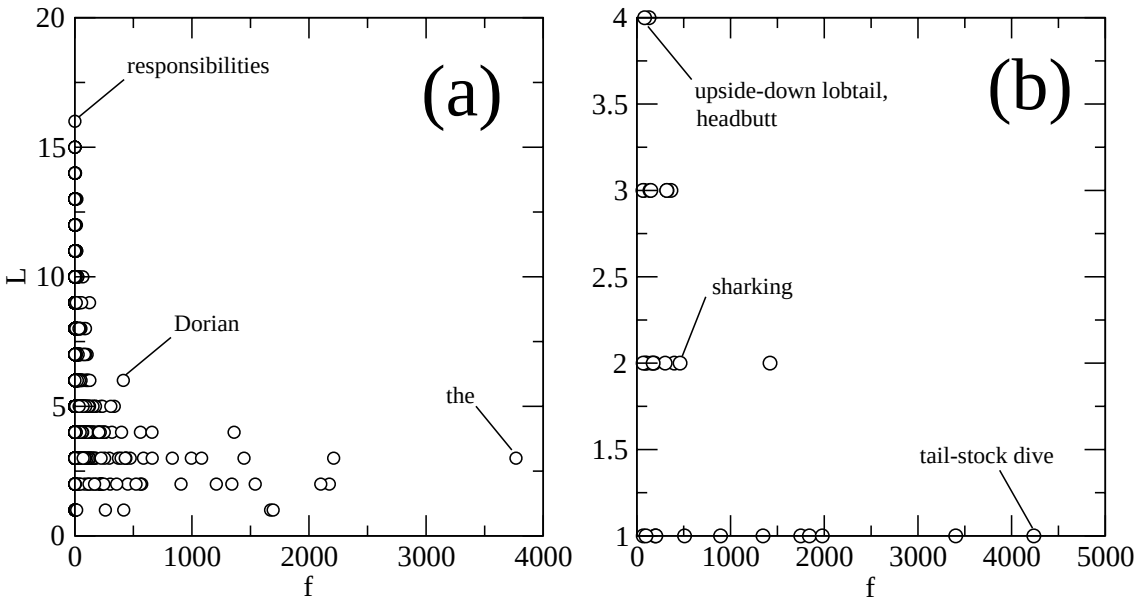

Figure 1. Length or size (L) versus frequency (f). (a) Words from the *Picture of Dorian Gray*, by Oscar Wilde (obtained freely from the Project Gutenberg, www.gutenberg.org). (b) Dolphins surface behavioural patterns. Some words and patterns are highlighted.

Table 1. The composition and the size (in behavioral units) of dolphin surface behavioural patterns.

Pattern	Behavioral unit	Size
Active surfacing	Fast	1
Bubble blow	Bubbles	1
Back-flop	Jump + back	2
Change of direction	Turn	1
Chase	Fast + two+ follow	3
Eye out	Head + lift	2
Fart blow	Fart	1
Forced blow	Chuff	1
Headbutt	Jump + two + hit + head	4
Headbutt miss	Jump + two	2
Head flop	Partial jump + side	2
Horizontal jump	Jump	1
Lobtail	Stationary + hit + tail	3
Pounce	Two + hit	2
Side flop	Jump + side	2
Sharking	Expose + dorsal fin	2
Snaggle	Stationary	1
Spy-hop	Stationary + expose + head	3
Side-swim	Side	1
Throat flop	Jump + hit + throat	3

Tail out	Stationary + expose + tail	3
Tail-out dive	Arch + tail	2
Tail-out jump	Partial jump	1
Tail slap	Two + hit + tail	3
Tail-stock dive	Arch	1
Twisted jump	Jump + twist	2
Twisted surface	Twist	1
Upside-down lobtail	Upside + stationary + hit + tail	4
Vertical jump	Jump + vertical	2
Carry weed	Carry	1
Weak lobtail	Hit + tail + weak	3